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I, JULIE BILLINGSLEY, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. PS 3270 for a patent by KABAY & COMPANY PTY LTD and VSL INVEST SUBCO 1 PTY LTD as filed on 28 June 2002.

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Ninth day of July 2003

J. Billingsley

JULIE BILLINGSLEY
TEAM LEADER EXAMINATION
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AUSTRALIA

Patents Act 1990

PROVISIONAL SPECIFICATION

for the invention entitled:

"AN ELECTROLUMINESCENT LIGHT EMITTING DEVICE"

The invention is described in the following statement:

AN ELECTROLUMINESCENT LIGHT EMITTING DEVICE

Field of the Invention

The present invention relates to a thick film electroluminescent light emitting device.

Background of the invention

The phenomenon of electroluminescence was discovered by Destriau in 1937. He demonstrated that in strong alternating electric fields certain doped Zinc Sulfide particles (commonly known as phosphors) emit light by means of luminescence.

Using the phenomenon of electroluminescence, it is possible to construct electroluminescent devices, such as lamps. An electroluminescent lamp is generally considered to be a light emitting parallel plate capacitor, typically having a dielectric media between two conductive electrodes, where one of the electrodes is semi-transparent. Electroluminescent particles known as phosphors are dispersed in the dielectric media. Light is emitted when an alternated electrical power source, ranging from around 30-300 V and 50-3000 Hz is connected to the electrodes. The term "lamp" in the present application is intended to cover the range of different applications applicable to electroluminescent devices.

In the present application, thick film electroluminescent lamps are defined as having phosphor particles typically sized the range of 10-70 microns. The phosphor particles are typically agglomerates of smaller particles, but the agglomerates form distinct particles. Thick film layers can be deposited by a range of known, generally low cost techniques, including screen-printing

G. Ross Fleming (Ref: Proceedings of the SID Vol. 30/3 1989) set the point of reference and standard by which prior art thick film electroluminescent lamps can be judged, stating that most commercial thick film electroluminescent lamps provide 20-30 ftL of light with a half-life of 1000 hours when driven at 115 V RMS and 400 Hz. Half-life is defined as the time taken for the light emitted from a lamp to fall to half its initial output, for a given set of conditions.

Another form of electroluminescent lamp employs thin film technology to create the light-emitting layer. Thin film electroluminescent lamps typically use a phosphor layer having a

cross sectional thickness in the order of 0.5 to 1 micron, which may be deposited by a range of techniques such as evaporation, sputtering, or atomic layer epitaxy (ALE). Whilst thin film electroluminescent lamps produce higher light outputs than thick film lamps, the production techniques required significantly increase the cost of the lamp. Thick film electroluminescent lamps therefore have a significant cost advantage over thin film devices, while generally operating at reduced light output. In the present specification, reference to an electroluminescent lamp will generally refer to a thick film electroluminescent lamp.

There are a number of limitations on the performance and applications of thick film electroluminescent lamps. The main interrelating performance characteristics are brightness, useful life and power consumption. Typically for a given lamp, these characteristics are commonly derived at a specific driving voltage and frequency (usually 115V RMS and 400 Hz). There is a trade off between brightness and life of a lamp, as increasing the brightness of a lamp by increasing the driving voltage or frequency typically results in the reduction of the effective (or half) life of that electroluminescent lamp.

Some other variables effecting performance include transmissivity and conductivity of the transparent electrode, phosphor characteristics, characteristics of the matrix material chosen and other characteristics of the layers, such as thickness.

A typical construction of a thick film electroluminescent lamp of the prior art consists of a planar back electrode to which an insulating layer is applied. A light emitting layer, including a discrete phase of phosphor particles suspended in a continuous phase such as a dielectric matrix, is then applied. The light emitting layer is covered with a planar electrically conducting semi-transparent front electrode layer through which the light is transmitted. This method of construction is referred to as "bottom up", as the bottom or non-transparent electrode layer is layed first, and the top, semi-transparent layer is laid last. Alternatively, the lamp may be constructed starting from the top or semi-transparent electrode. This later construction method can be termed "top down" as the top, semi-transparent electrode is laid down first, with subsequent layers added and the bottom electrode layer laid down last.

Both methods of construction result in an electroluminescent lamp. To generate light from the lamp, an alternating voltage is applied between the electrodes to excite the phosphor particles.

Electroluminescent lamps may be used in a variety of applications, including back-lighting of screens, such as those used in mobile telephones or personal digital organisers, and instrument panels on aircraft and vehicles. Further applications include electroluminescent display panels and signage.

The performance of thick film electroluminescent devices may be improved by decreasing power consumption, improving lumen efficiency, increasing useful (or half) life, increasing brightness, or a combination of the above.

A problem with electroluminescent lamps is in increasing the brightness of the lamps without compromising other performance characteristics. Increased brightness can be achieved by increasing the driving voltage or frequency. This can lead to increased power consumption, decreased efficiency, reduced life or even a breakdown in the material of the lamp.

It is therefore desirable to construct a thick film Electroluminescent lamp having improved performance over known thick film lamps, without resorting to expensive construction techniques.

Summary of the Invention:

In accordance with one aspect of the invention, there is provided a thick film electroluminescent lamp having a plurality of layers including:

a first electrode layer;

a light emitting layer having phosphor particles causing protrusions in the light emitting layer;

at least one other layer including a second electrode layer;

wherein the first electrode layer and the at least one other layer conform to the protrusions in the light emitting layer.

Preferably the at least one other layer includes an insulating layer and the second electrode layer.

Preferably the insulating layer contains a dielectric material.

Preferably, one of the electrode layers is partially transparent.

Without wishing to be bound by theory, it is believed that the aforementioned invention provides a more concentrated electrical field within individual phosphor particles. It is also believed that the arrangement of both conforming layers surrounding the phosphor particles produce electric filed lines which bend significantly more favourably to the shape of the phosphor particles, and therefore the field lines are closer to perpendicular to the surface of the particles. The abovementioned features result in an increased light output from a thick film electroluminescent light emitting device.

In one form, the conforming partially transparent electrode is of a substantially uniform thickness. This provides the advantage that the light travelling through the conforming electrode will not be diminished unevenly. Further, an electrode that is substantially uniform in cross sectional thickness will provide a more even electrical conductivity across its surface thereby assisting in the production of an even light from the electroluminescent lamp.

In one form the insulating layer contains a dielectric material.

Preferably, the phosphor particles causing protrusions in the light emitting layer are coated by an insulating material that prevents the phosphor particles from direct electrical connection to one or both of the electrode layers.

In one form the insulating material is a moisture resistant layer covering individual phosphor particles.

One form the light emitting layer includes a single layer of phosphor particles in a binder matrix.

In an alternative form, the light emitting layer includes two or less layers of phosphor particles are arranged in the binder matrix.

Preferably, the phosphor particles are arranged in an essentially close packed arrangement.

Preferably, the phosphor particles have diameters between 10 and 70 microns.

More preferably, the phosphor particles have diameters between 20 and 60 microns.

In another form of the present invention, a method of constructing a thick film electroluminescent device is provided, including the steps of:

(i). providing a light emitting layer having phosphor particles and a binder matrix;

(ii). providing an insulating layer having a sufficiently low viscosity during the manufacturing stage;

wherein the phosphor particles from the light emitting layer sink into the insulating layer to form a protruding layer that conforms to the insulating layer.

In a further form of the present invention, a method of constructing a thick film electroluminescent device is provided including the steps:

(i). applying an insulative layer to a first electrode layer;

(ii). providing a light emitting layer including phosphor particles in a binder matrix, the proportion of phosphor particles in the binder matrix being sufficient such that when solidified, a proportion of the phosphor particles cause protrusions in the light emitting layer;

(iii). applying the light emitting layer to the insulative layer; and

(iv). applying a second electrode layer;

wherein the insulating layer is heated above its softening temperature.

Preferably, the layer above and below the light emitting layer conform to the protrusions in the light emitting layer.

Preferably the layer above and conforming to the light emitting layer is an electrode layer.

Preferably the layer above and conforming to the light emitting layer is a partially transparent electrode layer.

Preferably, the layer below and conforming to the light emitting layer is an insulative layer.

It is not necessary to apply the conductive layer before the step of heating to the softening temperature. When the insulative layer and the light emitting layer reach a temperature above their softening point, the relatively dense phosphor particles sink partially into the insulative layer to cause the insulative layer to conform to the phosphor particles. It should

be noted that the phosphor particles may protrude from the matrix binder while still being covered with a layer of binder material. The conductive layer may be applied prior to heating the light emitting and insulating layer to their softening temperature, such that the conducting layer will cover the protruding phosphor particles in the light emitting layer, thereby forming a conforming surface.

Alternatively, the conductive layer may be applied after heating the light emitting and insulating layer to their softening temperatures. The conductive layer is then applied to conform to the phosphor particles protruding from the matrix of binder material.

Brief Description of the Drawings

Several embodiments representing examples of thick film electroluminescent lamps will now be described with reference to the accompanying diagrams, in which:

Figure 1 shows a schematic cross sectional view of an example of a thick film electroluminescent lamp of the present invention;

Figures 2(a)(i) and (ii) show two steps in a method of construction of the thick film electroluminescent lamp of figure 1;

Figure 2(b)(i) and (ii) shows two further steps in the method of construction shown in figures 2(a)(i) and (ii).

Figure 2(c) shows a cross section of the electroluminescent lamp constructed using the steps shown in figures 2(a)(i) and (ii) and 2(b) (i) and (ii);

Figures 3 (a) to (h) show graphs of the relative performance characteristics of example lamps compared to lamps of the prior art.

Description of the Preferred Embodiments

In figure 1, a portion of a cross section of an example of a thick film electroluminescent lamp 10 is shown. The lamp 10 includes electrode 11, a insulating layer containing a dielectric material, referred to as dielectric layer 12 and a semitransparent electrode 15. Also included is a light emitting layer 16 having a matrix of dielectric material 13 forming a continuous phase, surrounding phosphor particle 14, forming the discrete phase. Electrode layers 11 and15 are electrically connected to an alternating power source (not shown) such as an inverter supplying an output of 115v rms at 400Hz. Typical input

voltages to the power source vary but may be 6V DC from a battery source, or a photovoltaic cell.

As can be seen in figure 1, the light emitting layer has phosphor particle 14 protruding from the matrix of dielectric material 13. By protrusion, it can be seen that section 14a and 14b of the particle 14 cause surface features that generally protrude from the continuous phase of the dielectric material 13. The dielectric material 12 conforms to the shape of the part phosphor particle 14b, while not contacting the phosphor particle 14 itself due to dielectric material 13 surrounding the particle. Similarly, electrode 15 conforms to the shape of part of the phosphor particle 14a. The presence of the dielectric material 12 assists in forming an electric field between the electrodes. In some embodiments the phosphor particle 14 may contact an electrode (11 or 15).

A difference between a flat electrode surface typical of prior art lamps and the example shown in figure 1 is that there is a relative decrease in the distance between the electrode surface and light emitting layer 16. There is also an increase in size of the field generating layers (electrode layer 15 and dielectric layer 12), and as these layers are conforming to the phosphor particle 14, there is a corresponding increase in the exposure of the phosphor particle 14 to the electric field. Since the electrode layer 15 is conforming, it provides reduced transmission paths of generated light from the phosphor particle. As the electrode layer and dielectric layer are only partially transmissive of light, it is believed to be important to minimise the distance that light travels through these layers.

Constituent materials of phosphor particles 14 vary, and the example is not intended to be limited to a particular chemical composition of any material. It is believed that the improvement described in the example is achievable using a variety of inorganic phosphor particles used in thick film electroluminescent devices, including phosphor encapsulated to improve their moisture resistance.

A suitable material that may be used for the rear electrode 11 is an aluminium foil or carbon, although other suitable electrically conductive material may be used, including polymers coated with a conductive layer, depending on the application. Aluminium may be used where good reflective and electrical conductive properties are required.

The dielectric layer 12 may be partially translucent or reflective and may be formed from a combination of binder and barium titanate. Alternative materials known in the field of

technology may be used, and include silicon dioxide and titanium oxide. The dielectric layer is non-uniform in cross section, due to it conforming to the surface of the phosphor particles, however typically it is in the range of 5-30 microns.

The light emitting layer 16 typically includes phosphor particles dispersed in a binder material, such as ethyl cellulose, and is typically 20-70 microns thick.

The binder in the insulating and light emitting layers may be the same material depending on the desired properties and manufacturing techniques employed in creating the electroluminescent lamp.

A typical construction of an electroluminescent lamp, employing the bottom up method is shown in figures 2(a) (i), (ii), 2(b)(i), (ii), and 2(c).

Dielectric layer 112 is deposited on back electrode 111 as shown in figure2 (a)(i), with any coating method which can result in a substantially uniform 5-30 micron dry thickness, (screen printing, bar coating, roller coating, etc.) The coating paste consists of partially transparent resin binder used in the prior art, for example products selected from ethyl-cellulose group in solution with dimethylformamide, acetone, alcohols, or other suitable solvents. The coating paste also contains particles with high dielectric constant like barium titanate, and other titanates and zirconates used in the prior art to provide the layer with dielectric properties. The wet layer thickness is around 100 micron. The dried surface layer should ideally be highly reflective, smooth, uniform, and without pinholes, adhering to the back electrode. It is important to this method of constructing the layer that the softening point of the matrix of the dry layer is below or at the final softening temperature of the resin binder in the matrix of the light emitting layer.

The light emitting layer 116 is then deposited on the dielectric layer 112. The coating paste compositions in the light emitting layer consist of binder material 113, preferably the same as used for the insulating layer and electroluminescent phosphor particles 114. These phosphor particles 114 may be encapsulated with a moisture resistant barrier, or unencapsulated, and are available from suppliers such as Osram-Sylvania. However it is believed to be important to set up the proper phosphor – solvent – binder volume ratio (depending on the specific component materials chosen) such that after drying the printed layer, the top of the phosphor layer should have a rough surface as shown in figure 2(a)(ii). This roughness appears to originate from the volume of binder material in the light

emitting layer being insufficient to form a smooth top surface. This results in the projections of part of the phosphor particles shown in figure 1. The surface roughness, which defines the amount the phosphor particles project from the matrix, is typically in the order of 10-20 microns for phosphor particles in the size range of 10-70 microns. If the phosphor particles are substantially smaller than 20 microns, then it is envisaged that the surface roughness could be correspondingly smaller and the benefits of the example would still be achieved. Generally particles above 50 microns are difficult to obtain, and accordingly it is difficult to ascertain the performance of a device with these particles.

Ideally the phosphor particles 114 (discrete phase) are substantially homogeneously distributed through the binder material 113 (continuous phase when applied wet (as shown in figure 2(b)(i)). Upon drying, the phosphor particles 114 may have a cover of dielectric binder and protrude from the matrix to form an uneven upper surface 121. In figure 2(b)(I) an indium-tin oxide (ITO) containing layer has been added, which conforms to the protruding phosphor particles. The next stage of construction, shown in figure 2(b)(ii) is the drying of the electrode layer 115. As can be seen from figures 2(a)(i) and 2(a)(ii), the solvent in the electrode layer 115 evaporates on the uneven surface of the light emitting layer 116 to form a thinner layer.

There are several recipes for front or partially transparent electrode layer 115 described in the prior art, and most of them consist of polymer binder in solution, containing conductive particles such as indium oxide or indium-tin oxide (ITO) particles. Conductive polymers for this purpose have also been developed. Methods of application of the conducting layer include screen-printing or spraying. This layer may be also solidified in a way appropriate to the material chosen, such as drying or UV curing.

The last step is to deposit the silver bus bar, using commercially available pastes, such as available through Du Pont. The configuration of the bus bar is designed according to the lamp geometry and the area to secure uniform voltage over the entire semi-transparent electrode surface, and is known in the prior art.

In terms of uniformity of thickness of the transparent electrode layer 115, there is expected to be some thinning of the layer over the projecting phosphor particles, due to gravity and softening of the layer during a final heating stage. However, the degree of uniformity of

thickness of the surface layer is higher than if the electrode layer 115 had been applied to light emitting layer 116 such that the electrode layer 115 had a flat upper surface.

Following the bus-bar printing the next preparation step involves a softening stage, by heating the lamp to a temperature sufficient to soften the dielectric layer 12 and binder of the light emitting layer 16. The softening temperature may be, for example, between 170 to 190 degrees Celsius, for a time up to 30 minutes depending on the composition of the dielectric material. It should be noted that the other layers should be chosen to withstand the softening temperature.

In an alternative example, the softening stage may be applied before the application of the conductive electrode or bus bar. This allows greater freedom in selection of these materials, as they no longer need to withstand the elevated temperatures.

At the high temperature softening, as the insulating layer's binder reach a suitable softening stage, the denser phosphor particles will settle into the insulating layer. Further it is believed that the polymer surrounding the phosphor will shrink, and gases may be liberated, and the flexible front electrode layer will conform to the shape of the underlying phosphor particles. The degree of conformity of both sides of the light emitting layer increases at the softening temperature as the phosphor particles settle into the insulating layer. The softening further causes a volume reduction in the front electrode layer, which brings the conductive particles in the electrode in contact to each other, reducing surface resistance.

Electrical connections to the back electrode and the bus-bar are chosen according to application from methods described in prior art.

Depending on the type of phosphor used (with or without moisture protective encapsulation) the resulting light emitting sheet may be sealed in moisture protecting envelopes, which are essentially transparent plastics such as ACLAR or a PET plastic.

In figures 3(a)-3(h), graphs are shown of performance of examples made as described herein, compared to examples of the prior art. Figure 3(a) shows that at standard operating parameters of 115v rms and 400Hz, a lamp described herein may generate approximately twice as much light over its half life, compared to known lamps. In figure 3(b), it can be

seen that if a minimum brightness level is required from an electroluminescent lamp while operating at 115v rms and 400Hz, then lamps described herein may last twice as long.

From figure 3(c) it can be seen that if a starting output of 30 ftL is required, then a lamp described herein may only require 80v RMS at 400Hz, whereas a competitors lamp may require 115v rms at 400 Hz. It can also be seen that there is an accelerated rate of decrease in light output of the prior art lamps when attempting to run at 25-30 ftL.

Figure 3(d) shows that at a low voltage (48v RMS at 600Hz) the lamp described herein may show an increase in brightness without a correspondingly more rapid decrease in light output.

Figure 3(e) shows light output when a lamp described herein is compared to a lamp of the prior art, both run at 115 v RMS and 60 Hz. This voltage and frequency is typical of what might be expected from US mains power.

Figure 3(f) shows a graph of the light emitted from a lamp when the initial brightness is set to 50-55 ftL. As can be seen, the prior art lamp shows a more rapid decrease in light output, even though it is driven at a higher voltage (180 volts for the prior art lamp compared to 115v for a lamp described herein.

From the above it can be seen that increasing the voltage or frequency will increase the initial light output of an electroluminescent lamp, whether it be a lamps described herein or the prior art. However, running an electroluminescent lamp at a higher voltage or frequency results in reduced conversion of electricity into light. Figure 3(g) and 3(h) show that increasing voltage and frequency each produce a corresponding decrease in efficiency of a lamp. This results in increased power consumption for a given light output.

The claims defining the invention are as follows:

1 A thick film electroluminescent lamp having a plurality of layers including:

a first electrode layer;

a light emitting layer having phosphor particles causing protrusions in the light emitting layer;

at least one other layer including a second electrode layer;

wherein the first electrode layer and the at least one other layer conform to the protrusions in the light emitting layer.

2 The thick film electroluminescent light emitting device of claim 1 wherein the at least one other layer includes an insulating layer and the second electrode layer.

3 The thick film electroluminescent light emitting device of claim 2 wherein the insulating layer contains a dielectric material.

4 The thick film electroluminescent light emitting device of any preceding claim wherein the first or second electrode layer is partially transparent.

5 The thick film electroluminescent light emitting device of claim 4 wherein the conforming partially transparent electrode is of a substantially uniform thickness.

6 The thick film electroluminescent light emitting device of any one of claims 2 to 5 wherein the insulating layer contains a dielectric material.

7 The thick film electroluminescent light emitting device of any one of the preceding claims wherein the phosphor particles causing protrusions in the light emitting layer are coated by an insulating material that prevents the phosphor particles from direct electrical connection to one or both of the electrode layers.

8 The thick film electroluminescent light emitting device of claim 7 wherein the insulating material is a moisture resistant layer covering individual phosphor particles.

9 The thick film electroluminescent light emitting device of any preceding claim wherein the light emitting layer includes a single layer of phosphor particles in a binder matrix.

10 The thick film electroluminescent light emitting device of any one of claims 1 to 10 wherein two or less layers of phosphor particles are arranged in the binder matrix.

11 The thick film electroluminescent light emitting device of claims 9 or 10 wherein the phosphor particles are arranged in an essentially close packed arrangement.

12 The thick film electroluminescent light emitting device of any preceding claim wherein the phosphor particles have diameters between 10 and 70 microns.

13 The thick film electroluminescent light emitting device of claim 12 wherein the phosphor particles have diameters between 20 and 60 microns.

14 A method of constructing a thick film electroluminescent device including the steps of:

providing a light emitting layer having phosphor particles and a binder matrix;

providing an insulating layer having a sufficiently low viscosity during the manufacturing stage;

wherein the phosphor particles from the light emitting layer sink into the insulating layer to form a protruding layer that conforms to the insulating layer.

16 A method of constructing a thick film electroluminescent device comprising the steps:

applying a first insulative layer to an electrode layer;

providing a light emitting layer including phosphor particles in a binder matrix, the proportion of phosphor particles in the binder matrix being sufficient such that when solidified, a proportion of the phosphor particles cause protrusions in the light emitting layer;

applying the light emitting layer to the insulative layer; and

applying a second electrode layer;

wherein the insulating layer is heated above its softening temperature.

18 An electroluminescent device having a layer above and below a light emitting layer, wherein both the layer above and below the light emitting layer conform to phosphor particles projecting from the light emitting layer.

19 The thick film electroluminescent device of claim 18 wherein the layer above and conforming to the light emitting layer is an electrode layer.

20 The thick film electroluminescent device of claim 19 wherein the layer above and conforming to the light emitting layer is a partially transparent electrode layer.

21 The thick film electroluminescent device of claim 20 wherein the layer below and conforming to the light emitting layer is an insulative layer.

DATED this 28th day of June, 2002

Kabay & Company Pty Ltd
and
VSL Invest Subco 1 Pty Ltd

By DAVIES COLLISON CAVE
Patent Attorneys for the applicant

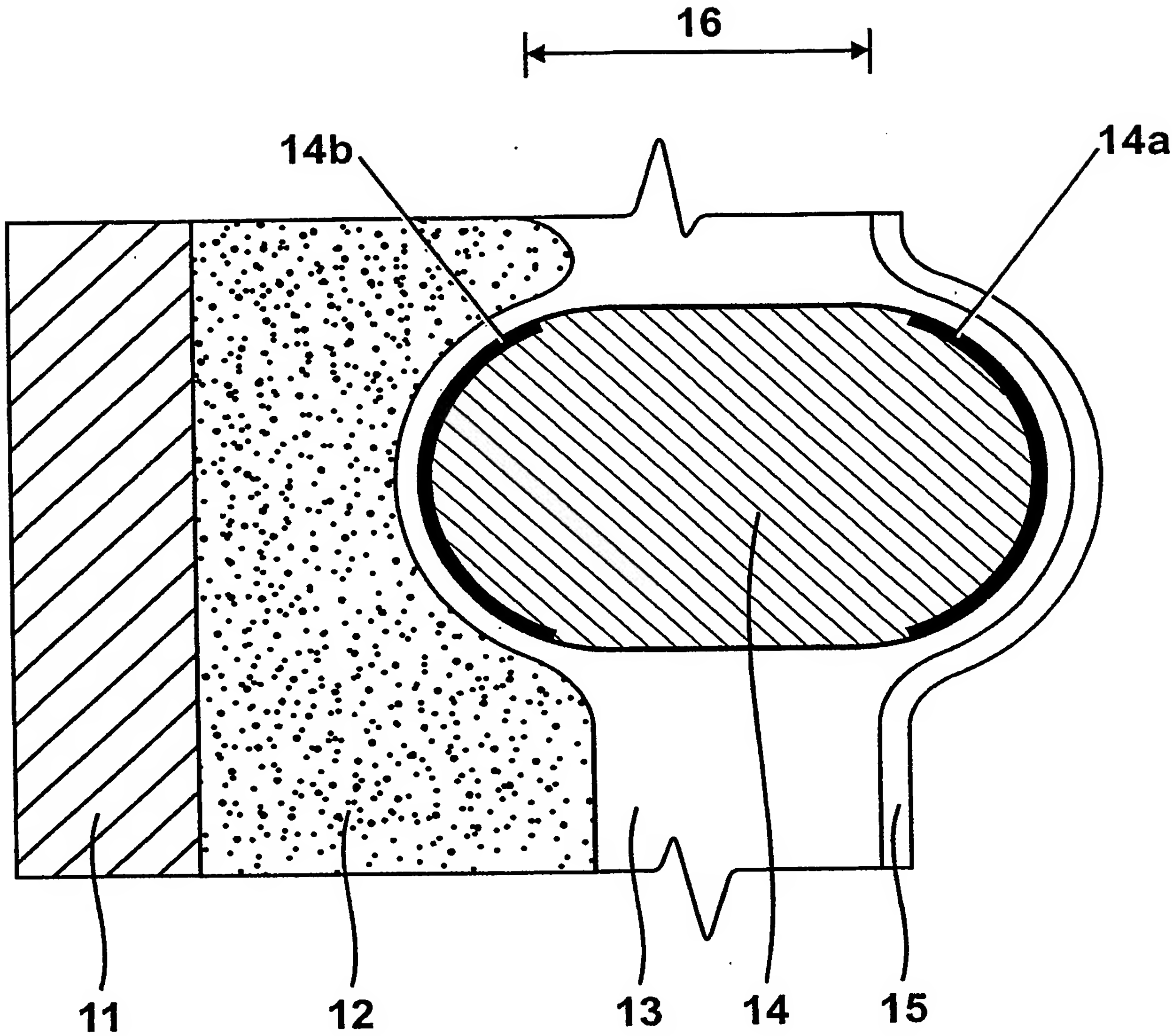


Fig.1

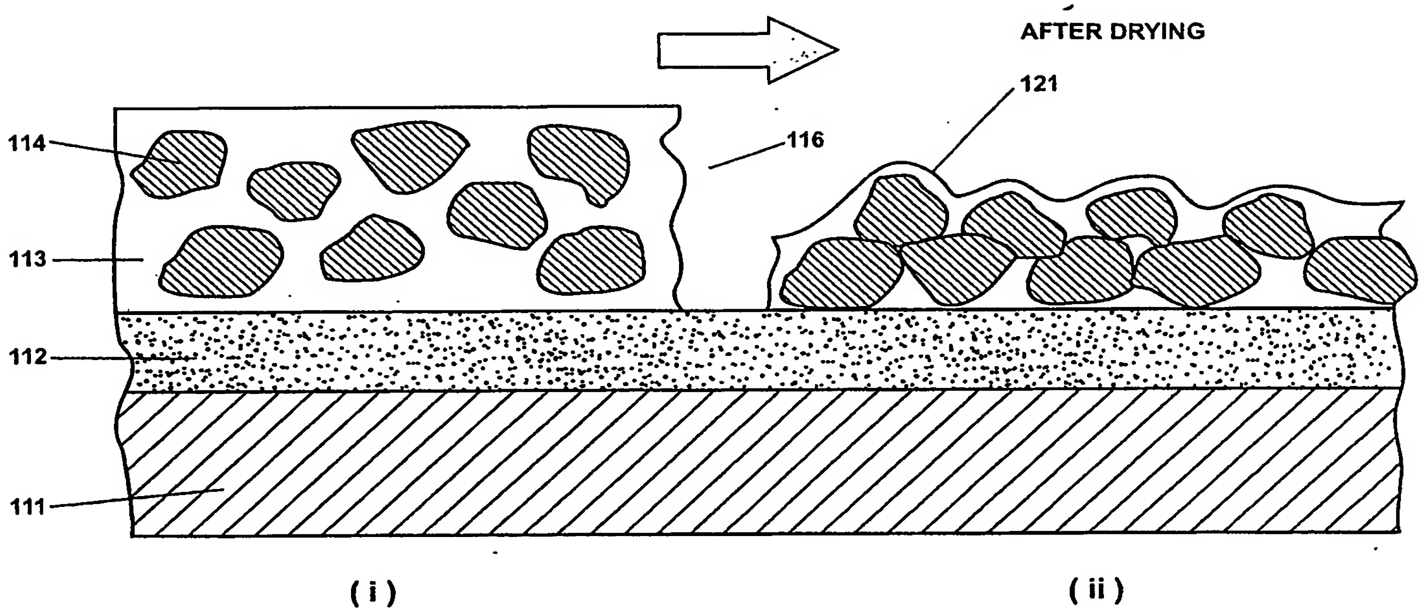


FIG. 2(a)

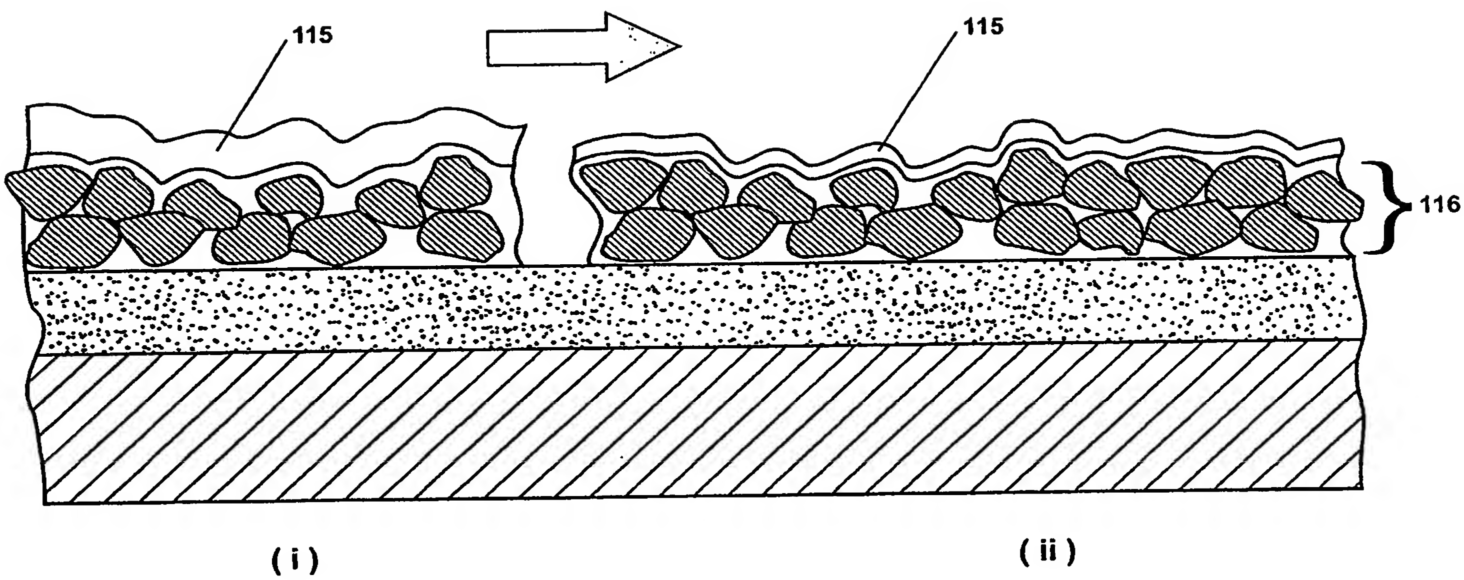


FIG. 2(b)

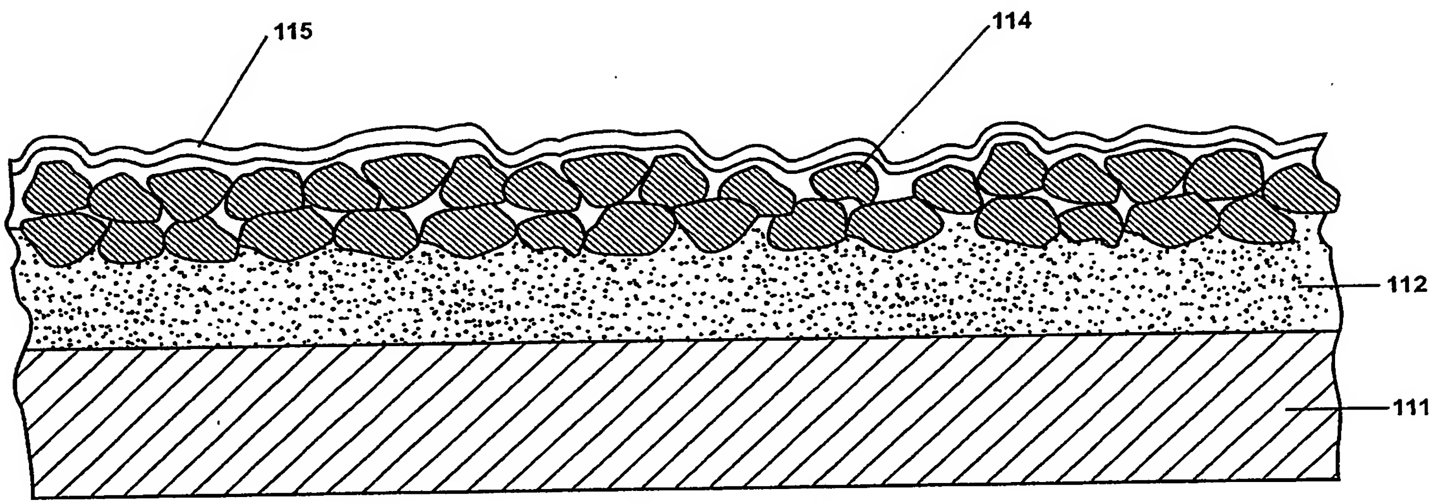


FIG. 2(c)

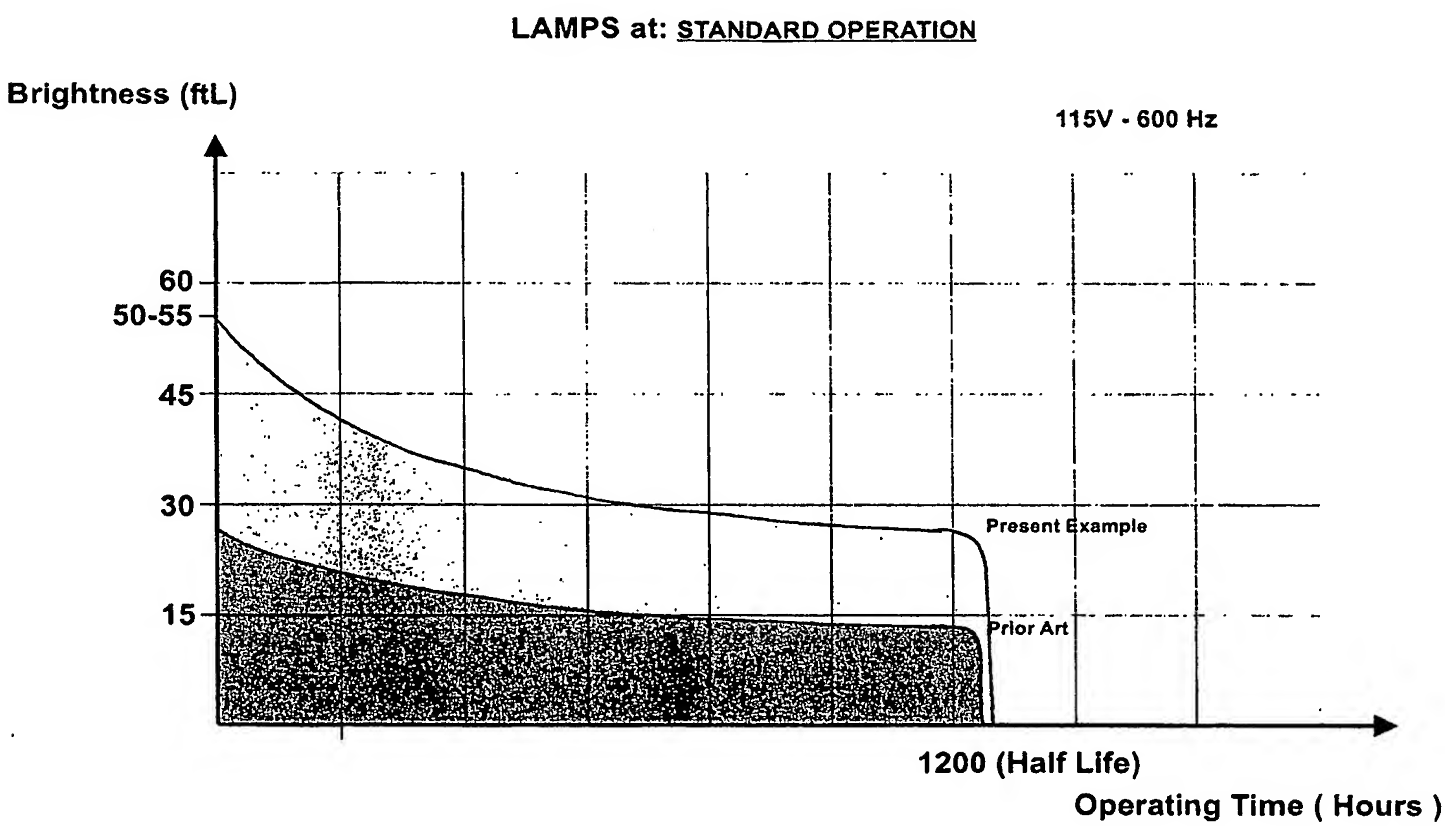

LAMPS at: STANDARD OPERATION
Brightness (ftL)
115V - 600 Hz
60
50-55
45
30
15
Present Example
Prior Art
1200 (Half Life)
Operating Time (Hours)

FIG. 3a

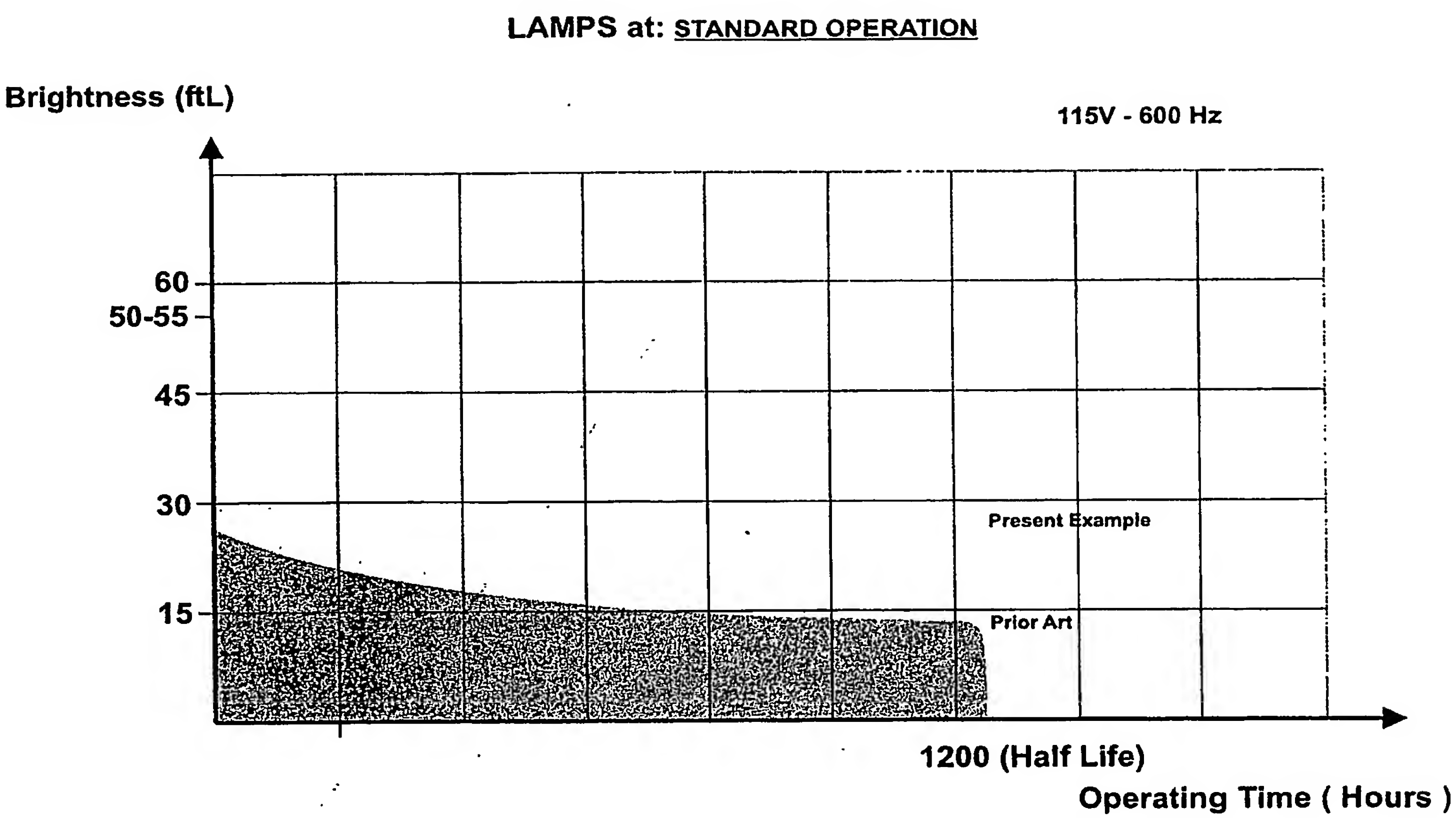

LAMPS at: STANDARD OPERATION
Brightness (ftL)
115V - 600 Hz
60
50-55
45
30
15
Present Example
Prior Art
1200 (Half Life)
Operating Time (Hours)

FIG. 3a

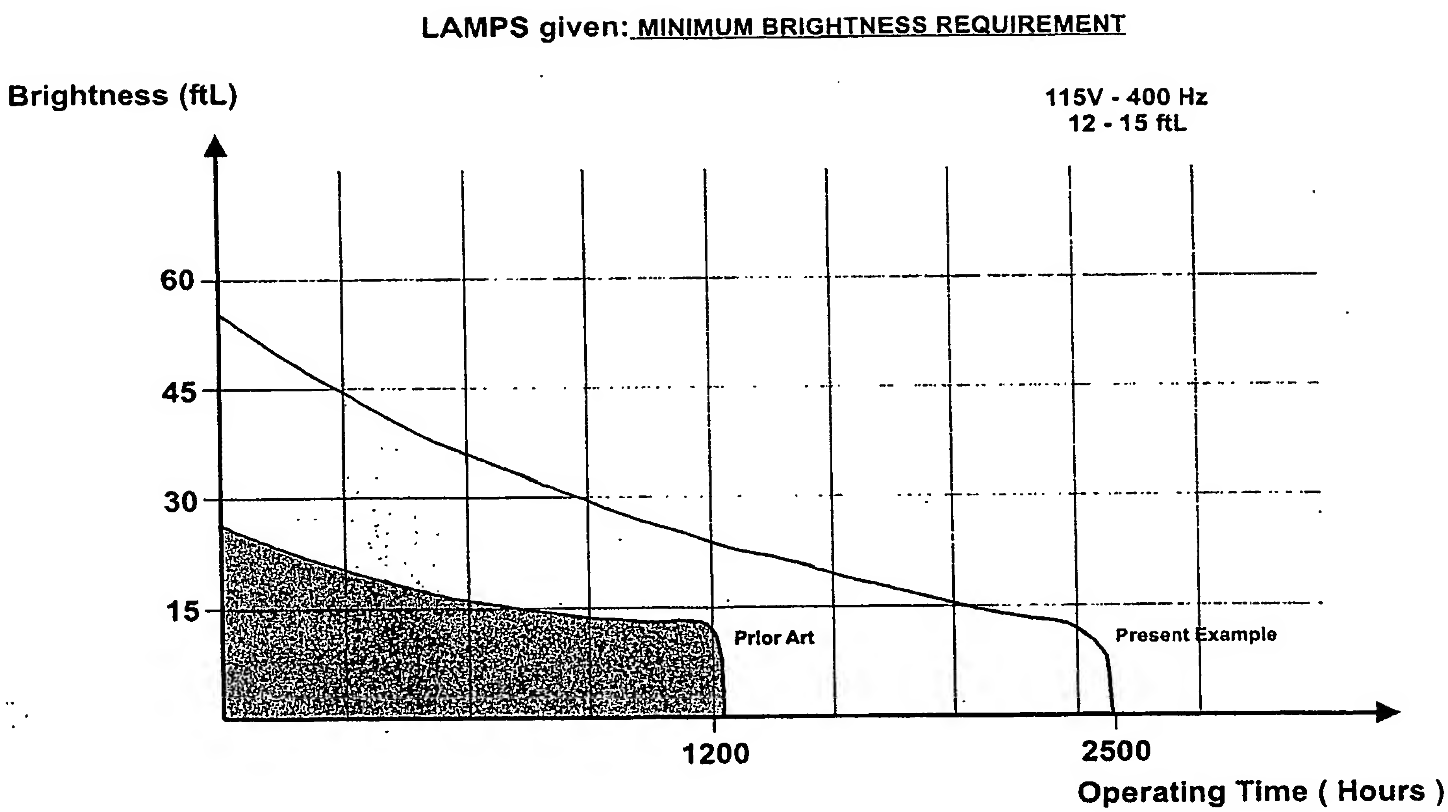

LAMPS given: MINIMUM BRIGHTNESS REQUIREMENT
Brightness (ftL)
115V - 400 Hz
12 - 15 ftL
60
45
30
15
Prior Art
Present Example
1200
2500
Operating Time (Hours)

FIG. 3b

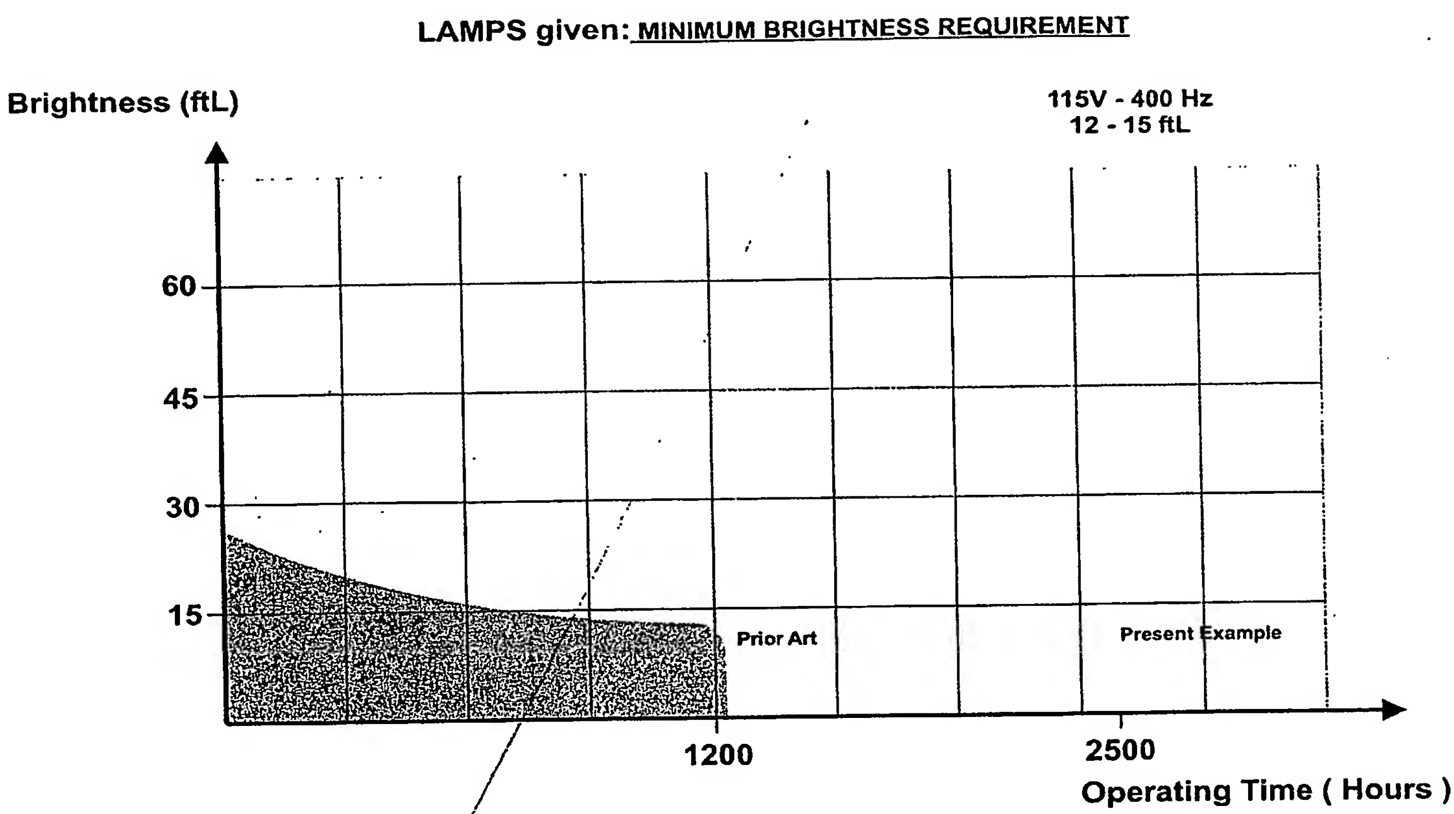
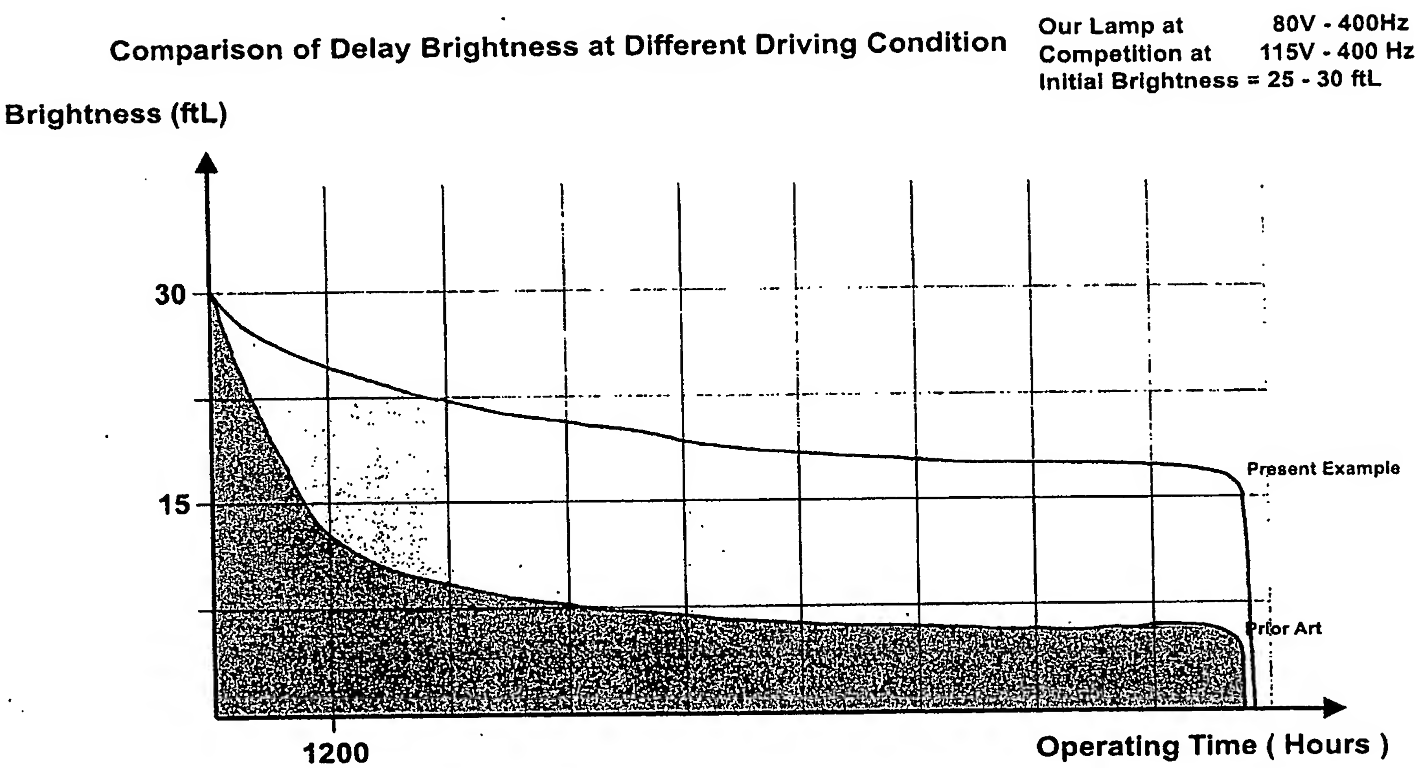

LAMPS given: MINIMUM BRIGHTNESS REQUIREMENT
Brightness (ftL)
115V - 400 Hz
12 - 15 ftL
60
45
30
15
Prior Art
Present Example
1200
2500
Operating Time (Hours)

FIG. 3b



Comparison of Delay Brightness at Different Driving Condition
Our Lamp at 80V - 400Hz
Competition at 115V - 400 Hz
Initial Brightness = 25 - 30 ftL
Brightness (ftL)
30
15
Present Example
Prior Art
1200
Operating Time (Hours)

FIG. 3c

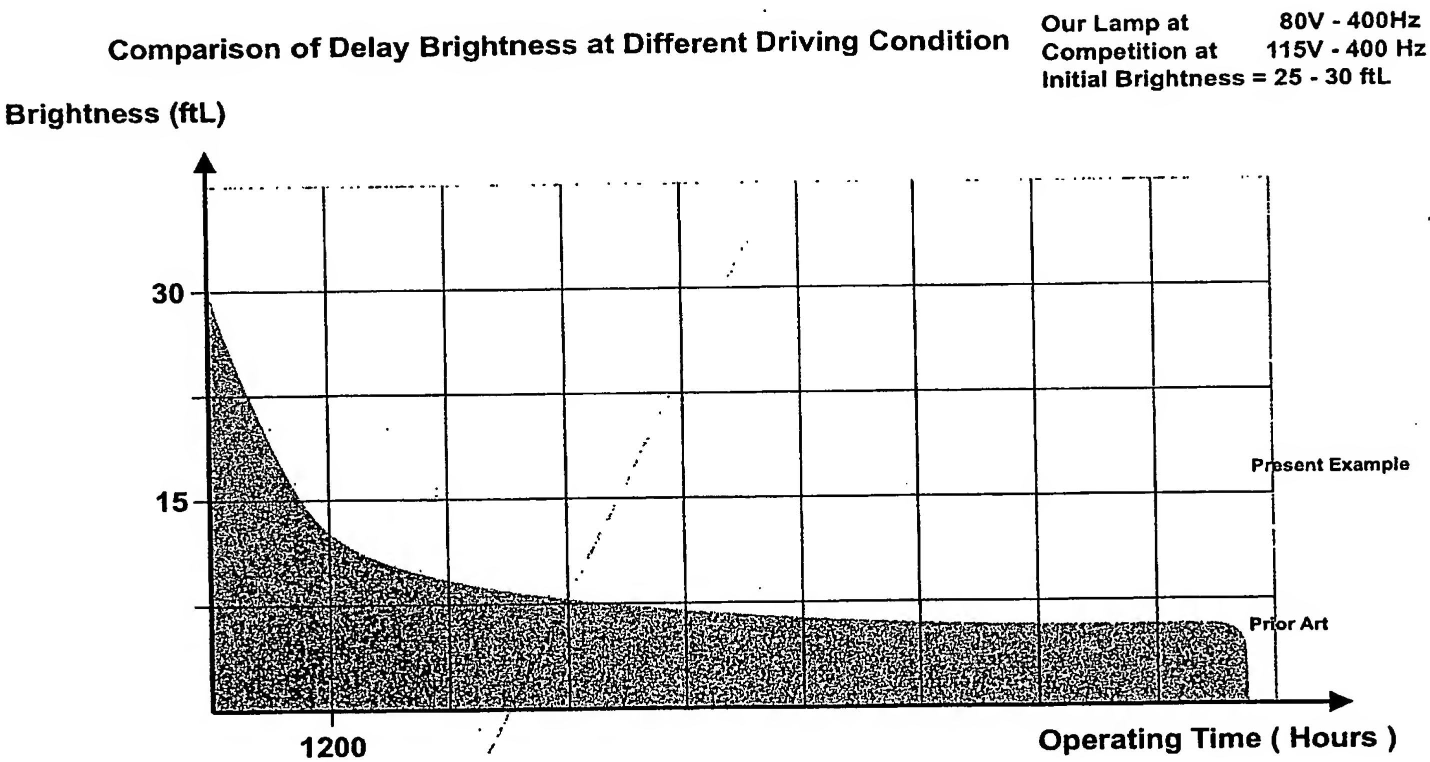

Comparison of Delay Brightness at Different Driving Condition
Our Lamp at 80V - 400Hz
Competition at 115V - 400 Hz
Initial Brightness = 25 - 30 ftL
Brightness (ftL)
30
15
1200
Operating Time (Hours)
Present Example
Prior Art

FIG. 3c

LAMPS at: LOW VOLTAGE OPERATION

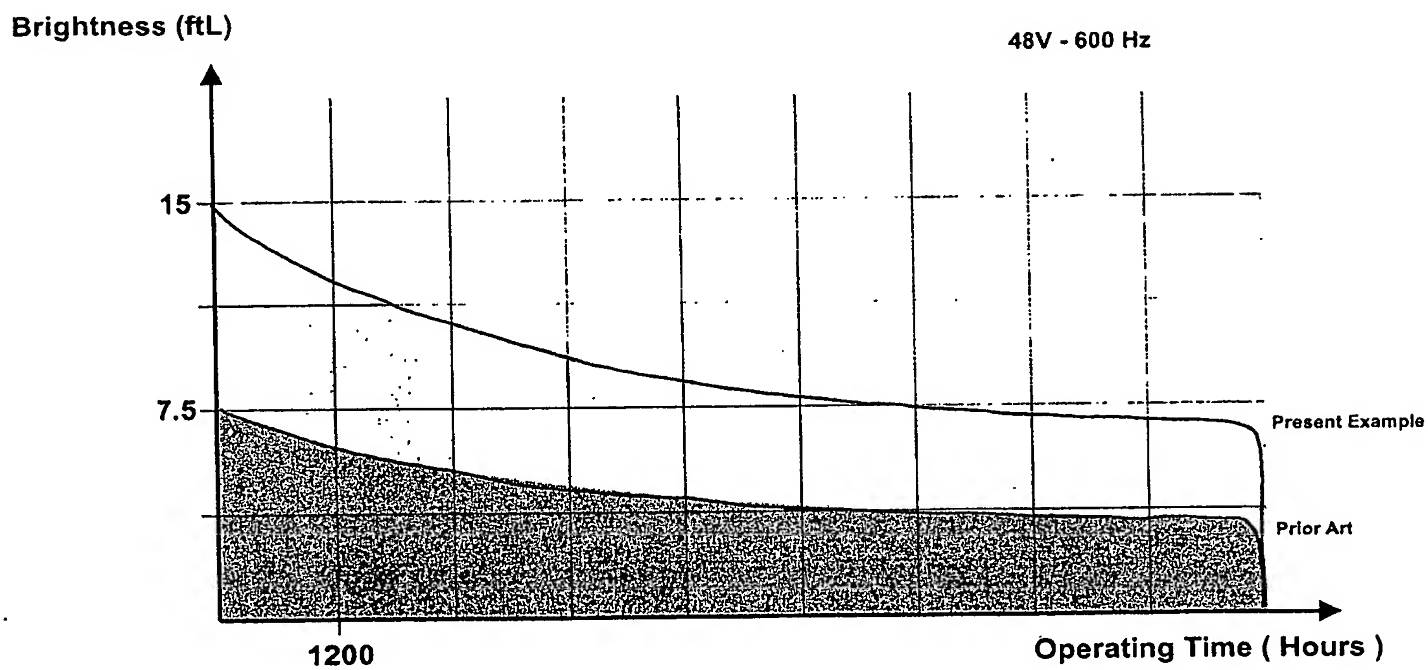


FIG. 3d

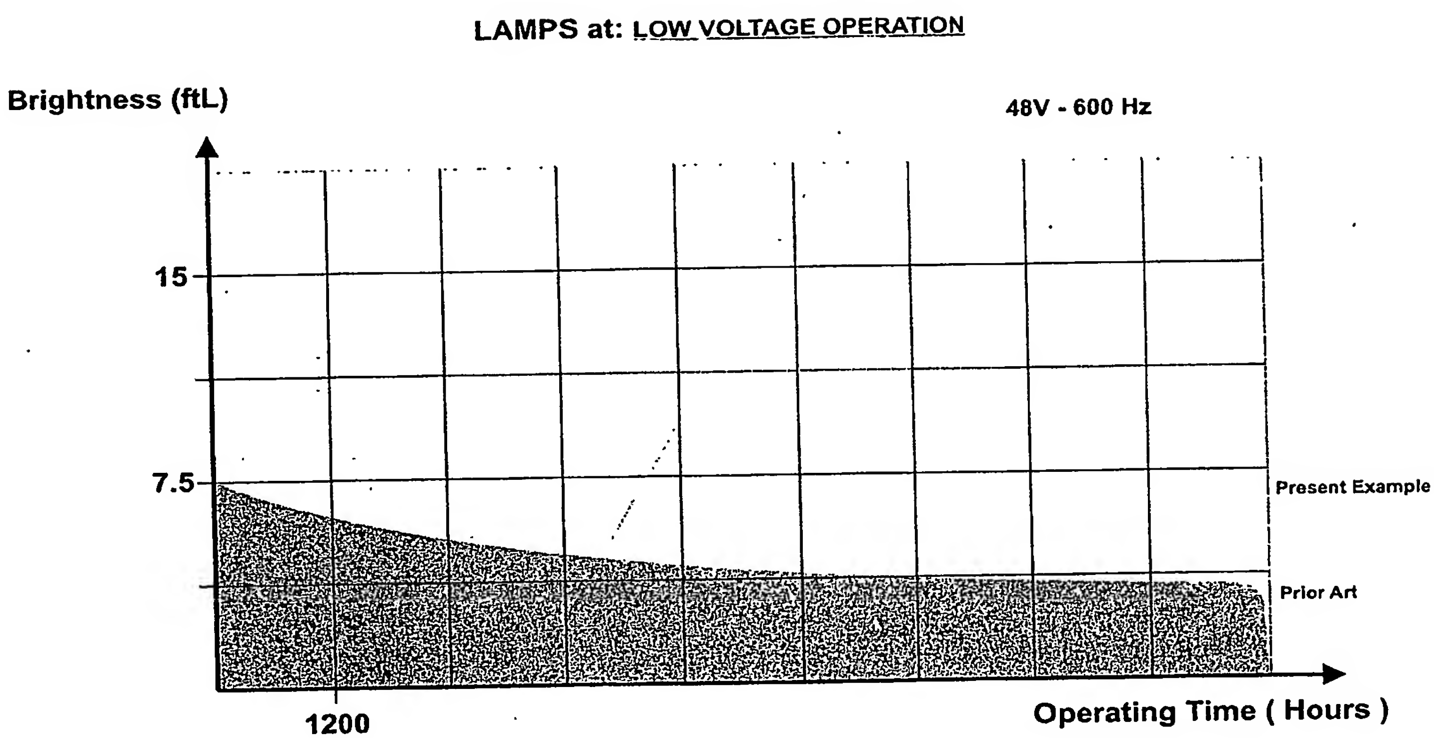

LAMPS at: LOW VOLTAGE OPERATION
Brightness (ftL)
48V - 600 Hz
15
7.5
Present Example
Prior Art
1200
Operating Time (Hours)

FIG. 3d

LAMPS when: POWERED FROM U.S MAIN

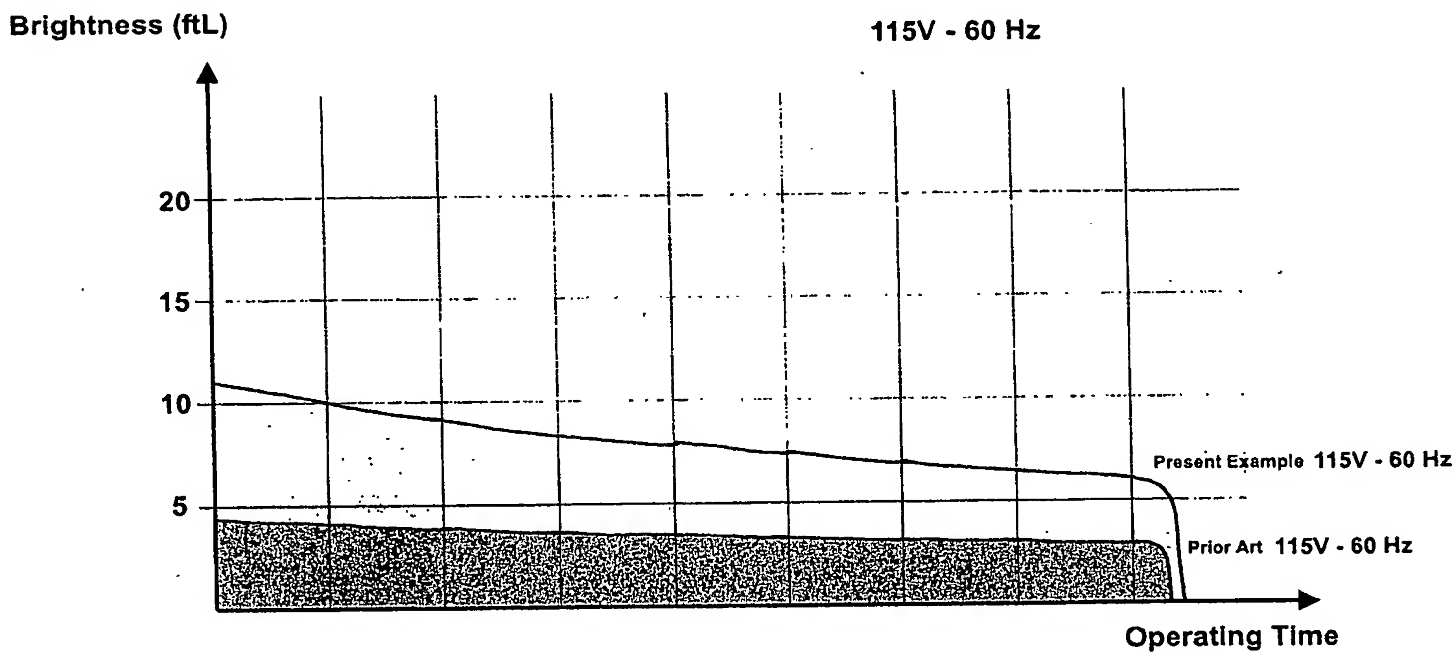


FIG. 3e

LAMPS when: POWERED FROM U.S MAIN

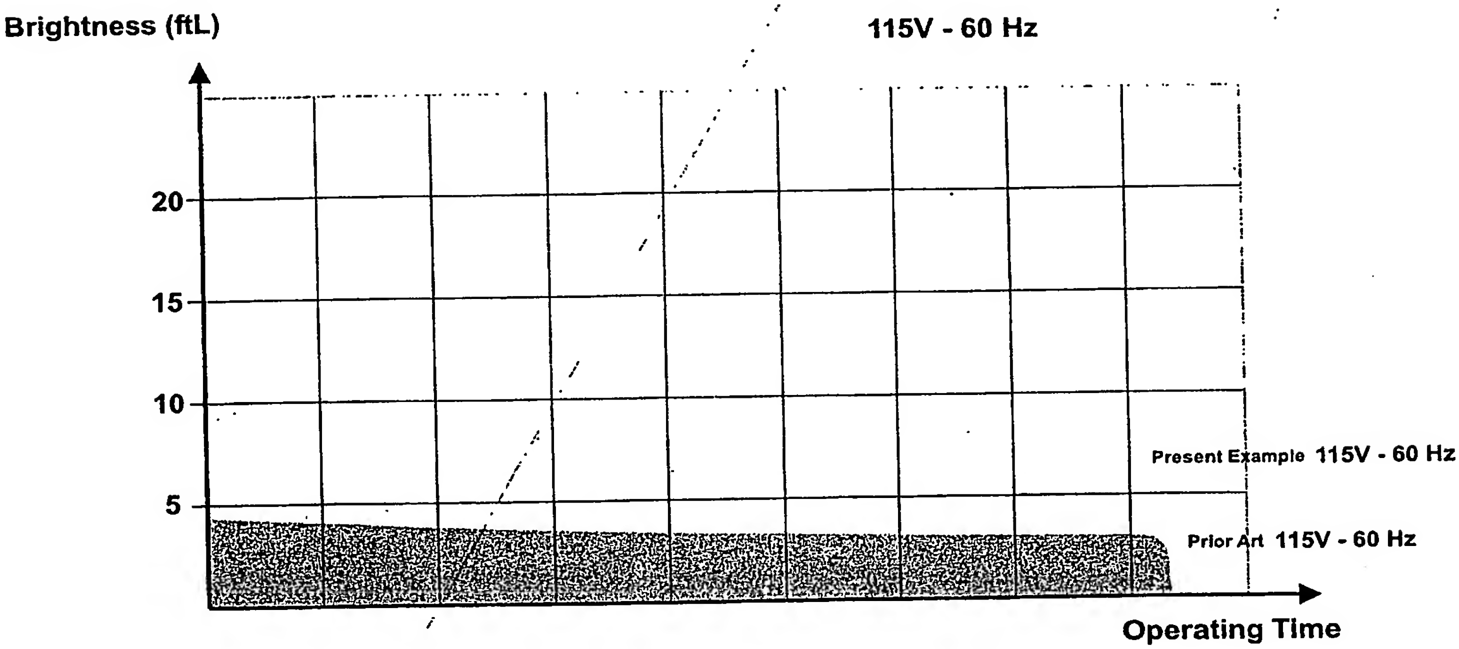


FIG. 3e

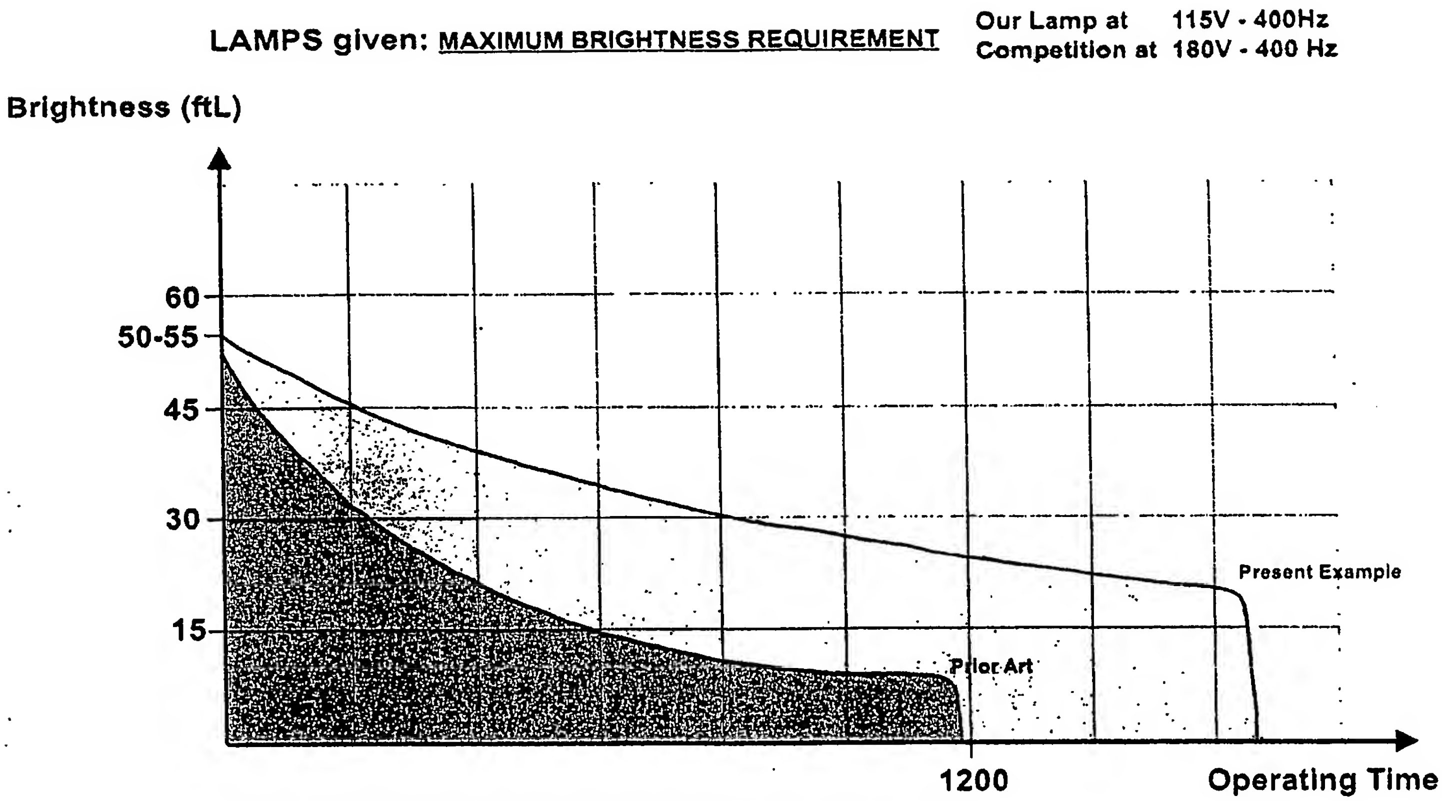

LAMPS given: MAXIMUM BRIGHTNESS REQUIREMENT
Our Lamp at 115V - 400Hz
Competition at 180V - 400 Hz
Brightness (ftL)
60
50-55
45
30
15
Present Example
Prior Art
1200
Operating Time

FIG. 3f

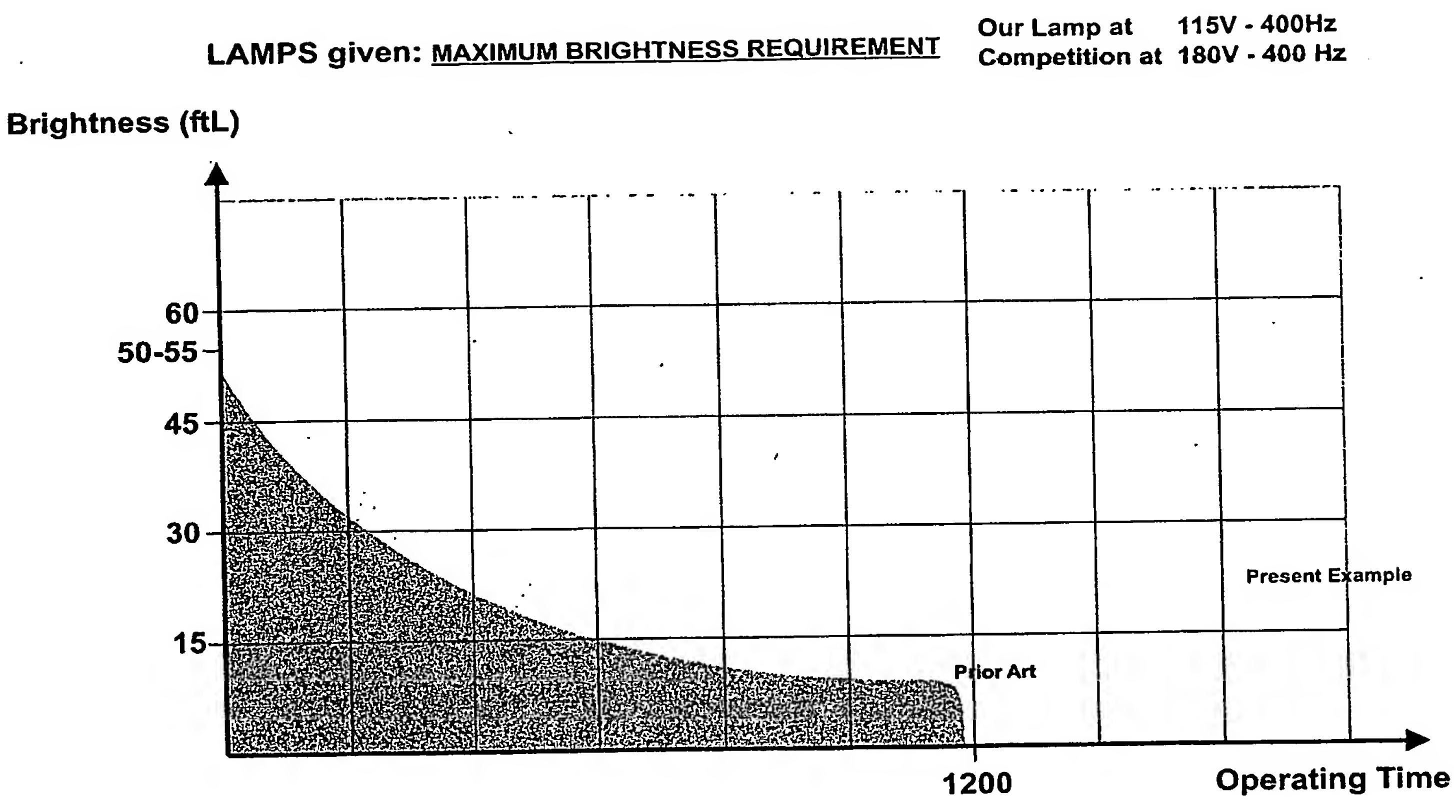

LAMPS given: MAXIMUM BRIGHTNESS REQUIREMENT
Our Lamp at 115V - 400Hz
Competition at 180V - 400 Hz
Brightness (ftL)
60
50-55
45
30
15
Present Example
Prior Art
1200
Operating Time

FIG. 3f

Efficiency as a Function of Voltage at 400 Hz

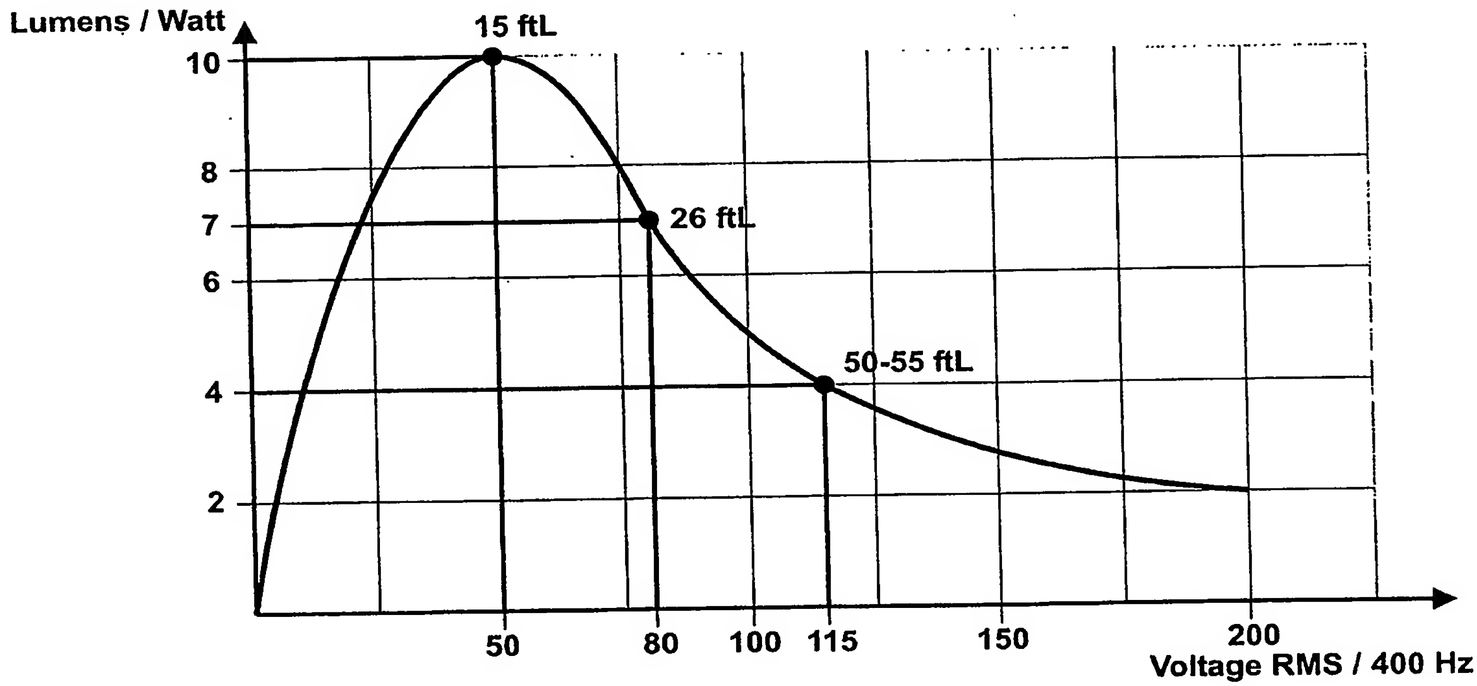


FIG. 3g

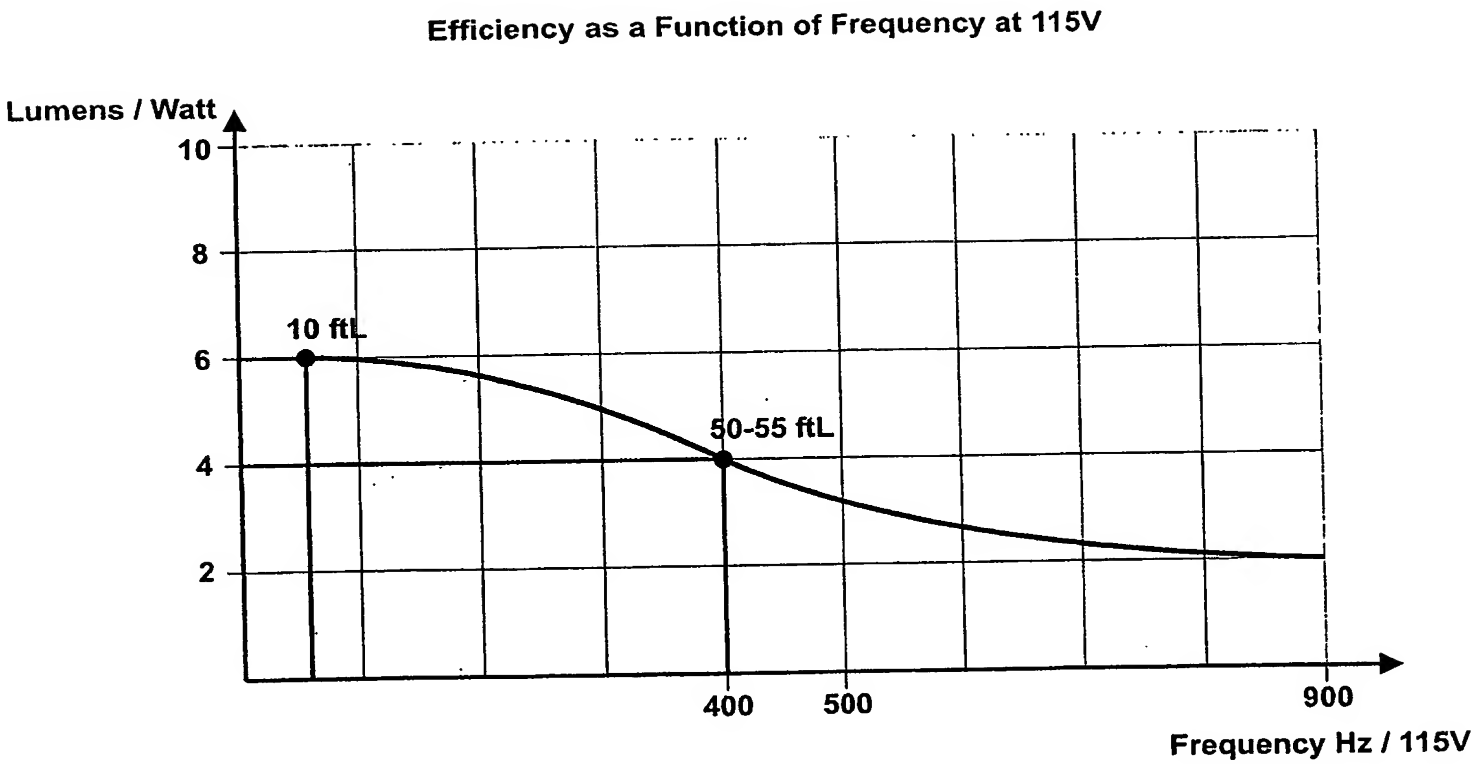

Efficiency as a Function of Frequency at 115V
Lumens / Watt
10
8
6
4
2
10 ftL
50-55 ftL
400
500
900
Frequency Hz / 115V

FIG. 3h